(NASA-TM-100168) AN EXPERIMENTAL INVESTIGATION OF PARASITIC MICROSTRIP ARRAYS (NASA) 15 p Avail: NTIS HC A02/MF A01 CSCL 09C

N87-27120

Unclas
63/33 0092689

AN EXPERIMENTAL INVESTIGATION OF PARASITIC MICROSTRIP ARRAYS

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Abstract

The characteristics of a parasitic microstrip antenna array with a center-fed patch are experimentally investigated. The parasitic array is composed of identical parasitic patches which are symmetrically arranged and electromagnetically coupled to a center-fed patch. The shape and dimensions of the parasitic patches and their positions relative to the center-fed patch are parameters in the study. To show mutual coupling effects between radiating and nonradiating edges of adjacent patches, the impedance and radiation characteristics of a three-element parasitic array excited with (0,1) mode are examined, and compared to that of a single patch. Experimental data indicate that the presence of parasitic patches has significant effects upon the gain, resonant frequency and impedance bandwidth of the array.

E-3731

Introduction

Using parasitic elements to enhance the bandwidth of a microstrip antenna patch have been studied by numerous researchers.[1-3] The antenna configurations generally consist of a center-fed patch with one or more adjacent parasitic patches of different resonant lengths. Such an arrangement improves the bandwidth, but is usually accompanied by a degradation of the pattern characteristics over the impedance bandwidth of the antenna.[1-2]

Very little work has been reported in the literature regarding the use of parasitic elements to enhance the gain of the antenna. Entschladen and Nagel[4] showed experimentally that enhancement in gain can be achieved with parasitic patches of identical sizes. This conclusion is supported by a theorectical model of Lee et al.,[5] who also point out the potential advantages of using parasitic subarrays as the basic unit for a large antenna array with MMIC (monolithic microwave integrated circuit) phase and amplitude controls.

The aim of this paper is to present some experimental results of impedance and radiation characteristics for a center-fed parasitic antenna array with identical parasitic elements.

Experimental Results

In the experiment, three antenna configurations were tested: a five-element cross (Fig. 1(a)), a three-element and a seven-element linear array of square and rectangular patches (Fig. 1(b)).

The rectangular patch having dimensions $a = 0.78$ cm and $b = 0.519$ cm was etched on a Cuflon substrate with $\varepsilon_r = 2.17$, and the 2 by 2 cm square patch was etched on a fibreglass substrate with $\varepsilon_r = 4.1$. In both cases, only the center patch was driven via a coaxial feed.

First, the impedance characteristics of a three-element square patch array consisting of a center-fed patch and two adjacent parasitic patches were investigated. The feed location was confined to the center-line along the y-axis at a distance, y_o, from the edge (Fig. 2) to ensure a single mode (TM_{01}) operation. For this feed position, the edges along the x-axis correspond to the radiating edges. The antenna configurations of Fig. 2(b) and (c) were tested to study the electromagnetic coupling between the radiating and the nonradiating edges respectively. In general, the parasitic elements enhance the impedance bandwidth as clearly indicated in the resistance curves (b) and (c) of Figure 2. The interaction is stronger between the nonradiating edges than the radiating edges. As a consequence, the impedance bandwidth of Fig. 2(c) is considerably broader compared with the bandwidth of Fig. 2(b), and is more than double the bandwidth of a single antenna. For the antenna configuration (c), the measured resonant frequency is about 3.46 GHz, and the impedance bandwidth with 10 dB return loss is about 6 percent.

The impedance loci for a five-element cross and a three-element linear parasitic array of rectangular patches are displayed on Smith chart in Figure 3. All patches are etched on 10 mil Cuflon substrates with 0.08 cm element spacing. Figure 3 shows that the presence of parasitic patches introduces loops in the impedance loci. The loop decreases in size and eventually degenerates into a cusp as the coupling between the parasitic patches and the driven patch is reduced. As indicated in curve (c) for the five-element cross, the impedance locus shows a large loop indicating a strong interaction between the nonradiating edges; a small loop and a cusp from weak coupling between the radiating edges. The appearance of the loops suggests that the parasitic elements behave like coupled multiple tuned circuits. Figure 4 shows the impedance loci for a five-element cross and a three-element linear parasitic array of rectangular patches etched on a 30 mil Cuflon substrate with 0.25 cm element spacing. Because of wider spacing and lower antenna Q associated with thicker substrates, the parasitic effect on the impedance characteristics is small. In Figures 3 and 4, the impedance loci for a single patch are also included for comparison purpose.

For antenna configurations of 3, 5, and 7 rectangular elements etched on 10 mil Cuflon substrates, the results of the gain and pattern measurements are summarized in Table 1 for the lowest mode (TM_{01}). As noted before, the presence of parasitic elements

shifts the resonant frequency slightly. The increase in gain and decrease in beamwidth are quite obvious. This happens because the parasitic elements derive energy from the excited patch through near field coupling, and re-radiate as discrete elements in an array. The interaction is stronger for closer spacing, as is evident from the data for $d = 0.24$ cm and $d = 0.08$ cm. For $d = 0.08$ cm, the gain increases from the single patch value of 4.9 to 8.6 db for the five-element cross and to 10 db for the seven-element linear array. The 3 db beamwidths are 50° by 55° and 80° by 16° respectively compared with 100° by 80° for the single patch.

The H and E plane patterns for the antenna configurations of Figure 1 were measured. The patterns for the thin rectangular patch (10 mil) with $d = 0.08$ cm are shown in Figures 5 and 6, and the patterns for the thick rectangular patches (30 mil) with $d = 0.08$ and $d = 0.25$ cm are shown in Figures 7 to 10. The patterns of the single patches are also provided for comparison. It appears that the presence of identical parasitic elements does not cause any serious degradation in the radiation patterns.

Conclusions

Experimental results indicate that, by placing identical parasitic patches adjacent to a driven patch, a broadside radiation pattern with significant enhancement in gain is obtained without any degradation of the pattern characteristics. The

impedance bandwidth is also broadened considerably, particularly, when the coupling is between the nonradiating edges of the antennas. The presence of parasitic elements introduces loops in the impedance loci, and thus, the parasitic elements act like coupled multiple tuned circuits. The loop reduces in size, and degenerate into a cusp as a result of weak coupling with wider element spacing and lower antenna Q. In general, the presence of parasitic patches alters the resonant frequency and the input impedance of the antenna.

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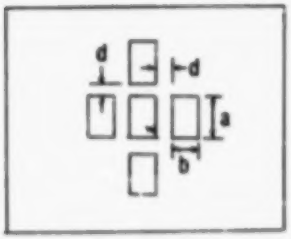
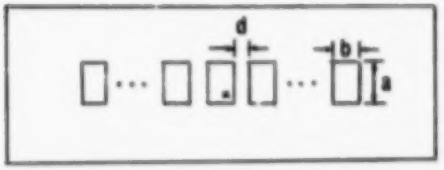
TABLE 1. - RADIATION CHARACTERISTICS OF MICROSTRIP ARRAYS WITH PARASITIC ELEMENTS

Antenna configuration	Interelement spacing d = 0.25 cm			Interelement spacing d = 0.08 cm		
	Resonant frequency, GHz	Gain, dB	3 dB beamwidths, deg	Resonant frequency, GHz	Gain, dB	3 dB beamwidths, deg
Single patch	12	4.9	100 x 80	12.7	4.9	100 x 80
3 element linear array	12.98	7.0	100 x 60	12.95	8.1	95 x 37
7 element linear array	12.84	7.8	81 x 57	13.0	10.0	80 x 16
5 element cross	12.87	6.5	100 x 60	13.19	8.6	50 x 55



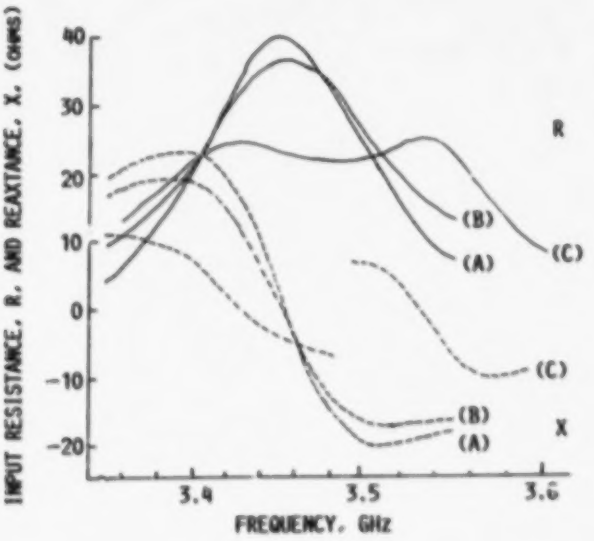
(A) 5-ELEMENT CROSS.

x - COAXIAL FEED



(B) 3 AND 7-ELEMENT LINEAR ARRAY.

FIGURE 1. - GEOMETRIES OF (A) A 5-ELEMENT CROSS AND (B) A 3 AND 7-ELEMENT LINEAR ARRAY FOR: $\varepsilon_r = 2.17$, a = 0.78 cm, b = 0.519 cm, d = 0.08 cm AND 0.25 cm.



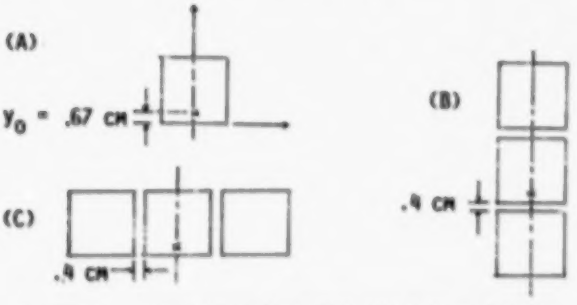


FIGURE 2. - IMPEDANCE PLOT FOR (A) 2x2 cm SQUARE PATCH, (B) AND (C) 3-ELEMENT LINEAR ARRAY.

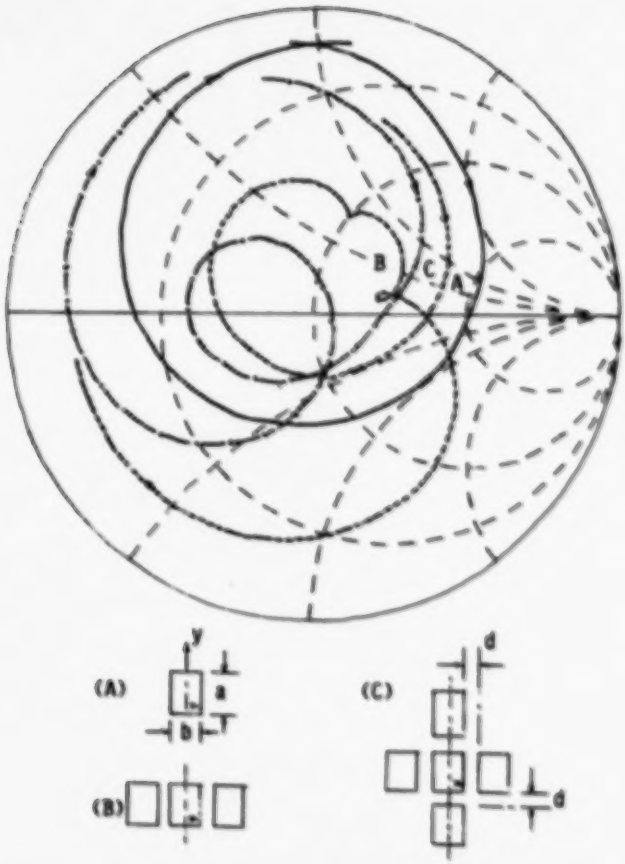


FIGURE 3. - IMPEDANCE LOCI FOR (A) A SINGLE MICROSTRIP PATCH, (B) A 3-ELEMENT PARASITIC ARRAY AND (C) A 5-ELEMENT CROSS FOR: ε_r = 2.17, a = 0.78 cm, b = 0.519 cm, d = 0.08 cm AND SUBSTRATE THICKNESS = 10 MIL.

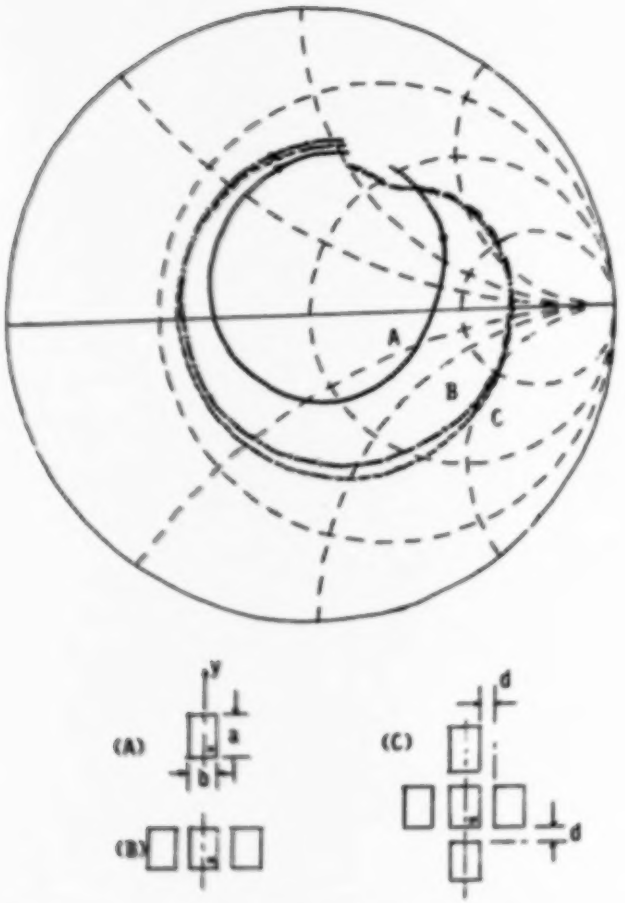


FIGURE 4. - IMPEDANCE LOCI FOR (A) A SINGLE MICROSTRIP PATCH. (B) A 3-ELEMENT PARASITIC ARRAY AND (C) A 5-ELEMENT CROSS FOR: ε_r = 2.17, a = 0.78 cm, b = 0.519 cm, d = 0.25 cm AND SUBSTRATE THICKNESS = 30 MIL.

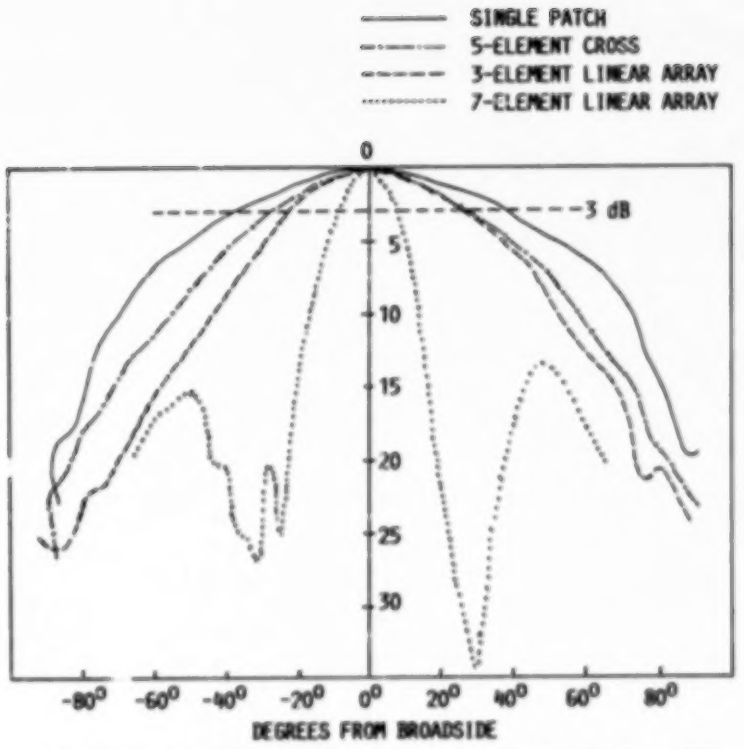


FIGURE 5. - H-PLANE PATTERNS FOR: ε_r = 2.17, d = 0.08 cm, AND SUBSTRATE THICKNESS = 10 MIL.

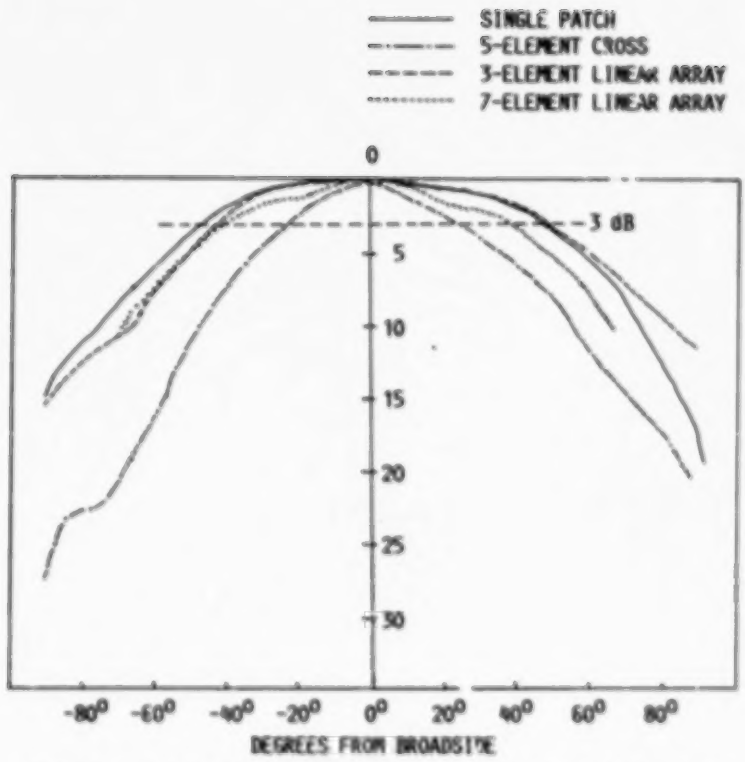


FIGURE 6. - E-PLANE PATTERNS FOR: ε_r = 2.17, d = 0.08 cm, AND SUBSTRATE THICKNESS = 10 MIL.

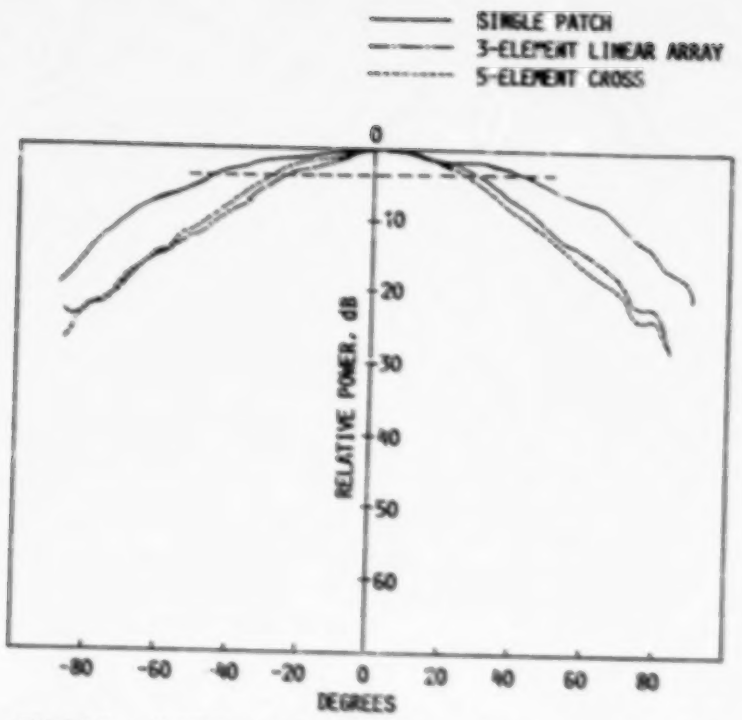


FIGURE 7. - H-PLANE PATTERNS FOR: ε_r = 2.17, d = 0.08 cm AND SUBSTRATE THICKNESS = 30 MIL.

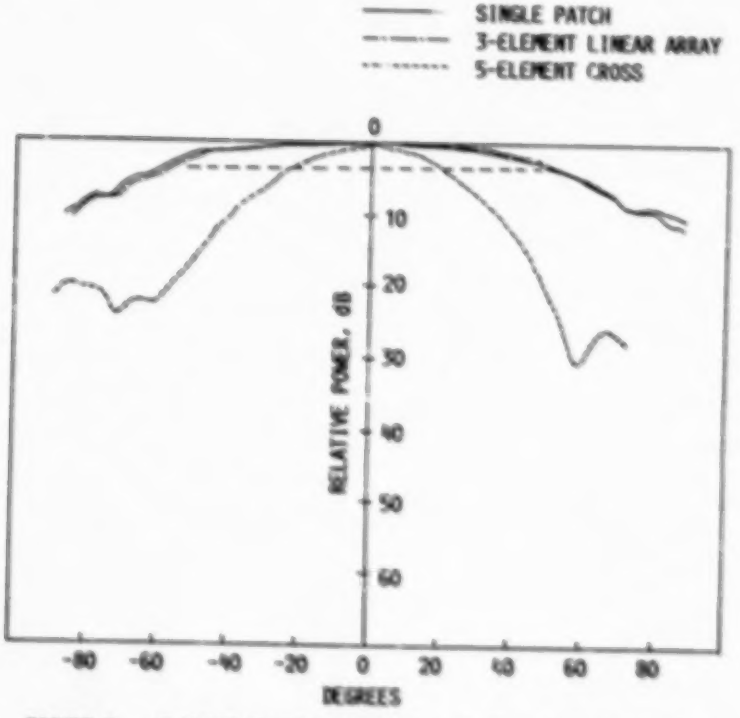


FIGURE 8. - E-PLANE PATTERNS FOR: ε_r = 2.17, d = 0.08 cm AND SUBSTRATE THICKNESS = 30 MIL.

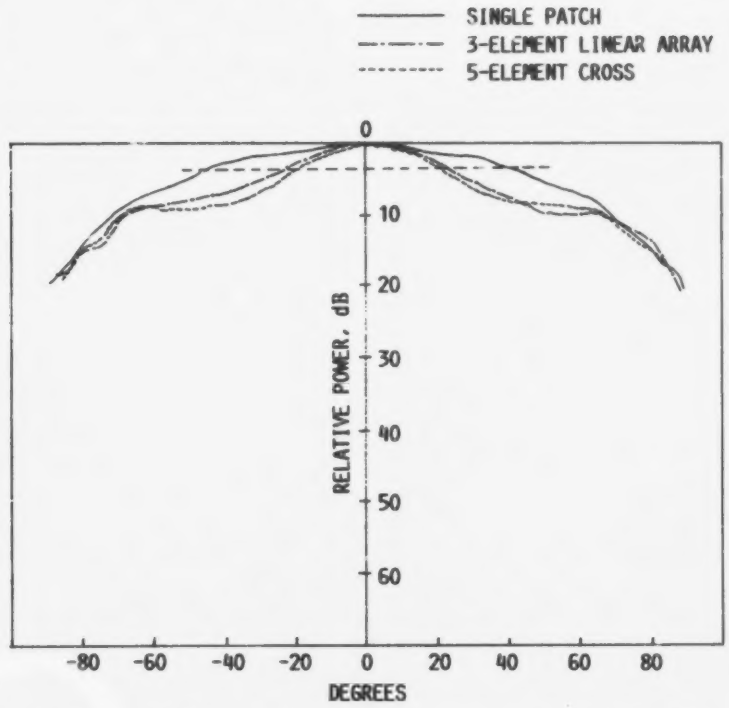


FIGURE 9. - H-PLANE PATTERNS FOR: ε_r = 2.17, d = 0.25 cm AND SUBSTRATE THICKNESS = 30 MIL.

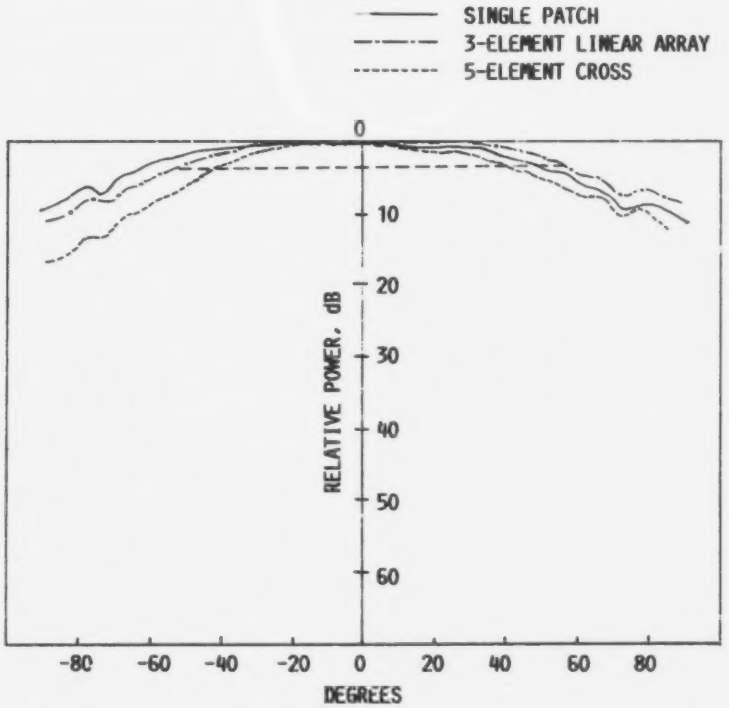


FIGURE 10. - E-PLANE PATTERNS FOR: ε_r = 2.17, d = 0.25 cm AND SUBSTRATE THICKNESS = 30 MIL.

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National Aeronautics and Space Administration

Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-100168		

4. Title and Subtitle

An Experimental Investigation of Parasitic Microstrip Arrays

5. Report Date

6. Performing Organization Code

7. Author(s)

Richard Q. Lee, Roberto Acosta, J.S. Dahele, and K.F. Lee

8. Performing Organization Report No.

E-3731

10. Work Unit No.

506-44-21

9. Performing Organization Name and Address

National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135-3191

11. Contract or Grant No.

13. Type of Report and Period Covered

Technical Memorandum

12. Sponsoring Agency Name and Address

National Aeronautics and Space Administration
Washington, D.C. 20546-0001

14. Sponsoring Agency Code

15. Supplementary Notes

Prepared for the 1987 Symposium on Antenna Application cosponsored by the University of Illinois and the Rome Air Development Center, Monticello, Illinois, September 23-25, 1987. Richard Q. Lee and Roberto Acosta, NASA Lewis Research Center; J.S. Dahele, School of Electrical Engineering and Science, Royal Military College of Science, United Kingdom; K.F. Lee, Department of Electrical Engineering, The University of Akron, Akron, Ohio 44325.

16. Abstract

The characteristics of a parasitic microstrip antenna array with a center-fed patch are experimentally investigated. The parasitic array is composed of identical parasitic patches which are symmetrically arranged and electromagnetically coupled to a center-fed patch. The shape and dimensions of the parasitic patches and their positions relative to the center-fed patch are parameters in the study. To show mutual coupling effects between radiating and nonradiating edges of adjacent patches, the impedance and radiation characteristics of a three-element parasitic array excited with (0,1) mode are examined, and compared to that of a single patch. Experimental data indicate that the presence of parasitic patches has significant effects upon the gain, resonant frequency and impedance bandwidth of the array.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Parasitic microstrip antenna Parasitic arrays	Unclassified - Unlimited Subject Category 33

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No of pages	22. Price*
Unclassified	Unclassified	14	A02

*For sale by the National Technical Information Service, Springfield, Virginia 22161